Globalization, modes of innovation and regional innovation systems

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Abstract

Individual firms increasingly transcend the boundaries of regional innovation systems in their search for information and knowledge, and only rarely can they build their knowledge bases on science system output alone. This challenges the coherence of the regional knowledge diffusion infrastructure, and the role of science and education system actors. The following chapter explores knowledge development and innovation processes of firms in a specialized Norwegian industrial region, and how the various institutions and actors which form this infrastructure are responding to emerging challenges. The paper concludes that regional universities and higher education institutions may play a vital role in supporting knowledge-based development, albeit different from that of science-based knowledge production.

Introduction

The competitiveness of firms and regions in a globalizing economy rests on their ability to continuously develop and exploit specialized knowledge assets. The development of such assets is contingent on the activities and networks maintained by individual firms(Giuliani, 2005); on the composition of the industrial structure (R. Boschma & Iammarino, 2009; Frenken, Oort, & Verburg, 2007); and on mechanisms which enable knowledge to flow and recombine between activities. As products and processes are becoming increasingly complex and the global division of labor deepens, firms are forced to draw on a wide range of component technologies and complementary capabilities (Rothaermel, Hitt, & Jobe, 2006) and combine leading scientific insights with specialized, experience-based knowledge (Danneels, 2002). Thus, innovation at the firm level is becoming embedded in global innovation networks (OECD, 2008; Trippl, Todtling, & Lengauer, 2009). Both research and policy is consequently forced to acknowledge the geographically distributed nature of firm-level knowledge development, and the diverse sources of information and knowledge upon which firms must draw. The process of globalization appear to favor those regions which develop information processing and knowledge absorption infrastructures (Simmie, 2003, 2004) able to link a set of technologically related albeit different, globalized actors (Giuliani, 2005; Graf, 2010) and industries (Lazaric, Longhi, & Thomas, 2008). Thus, with globalization follows a decreasing relevance of clusters defined as sets of co-located users and producers, but also an increasing relevance of untraded interdependencies (Storper, 1997), localized information and knowledge spillovers, and regional innovation systems (Verspagen & Schoenmakers, 2000).

This paper investigates first how industrial actors in two dominating sub-clusters of a Norwegian industrial region develop and use different forms of knowledge, by means of linking heterogeneous internal processes to various external actors groups located in the region, outside it and abroad. Second, it describes processes of transformation and adaption to this context on the side of institutionalized knowledge diffusion mechanisms, with particular emphasis on the emerging role of the regional university college. Third, it shifts focus back towards how this impact present industrial dynamics, and discusses how this impact could be reinforced by building on the transformation which has already occurred internal to the university college.

The Vestfold region is hosting a set of specialized and highly international companies within electronic- and microelectronic manufacturing (B. Asheim & Isaksen, 2002; Onsager, Isaksen, Fraas, & Johnstad, 2007) and maritime engineering. Vestfold is located on the Western shores of the Oslo fjord, approximately one hour by car from the capital city of Oslo. The evolution of the electronics cluster illustrates the interplay between external inputs, and the cumulative development of specialized knowledge assets at the regional level. The firms which would become core actors in the cluster where all established during the 1970s and early 1980s, and combined external science-based knowledge with pre-existing industrial competences and capabilities. This initiated a process of specialization into areas such as sensor technology, ultrasound technology and advanced communication equipment, from which numerous new firms would spin off during in particular the 1980s and 1990s. Throughout this process, firms continued to draw on research communities located outside the region. At present, the Electronic Coast collaborative network (EC-Network) consists of a stable population of 36 member firms, which operate in diverse international markets. Few of these are in direct competition with each other, and most are embedded in their individual global production and innovation networks. The maritime engineer group of companies consists of six large companies in segments such as oil and gas subsea constructions. The evolution of this industry in the region bear similarities to the evolution of the electronics cluster, in that it entailed a process by which pre-existing shipbuilding activities and competences where transformed into more advanced offshore engineering activities linked to scientific research and lead user firms located outside the region. The eight companies which recently formed the Engineering Coast network compete in the same market segment. They have less experience of formalized collaboration with each other, but may draw on the tradition of collaboration with the university college established by its shipbuilding predecessors.

Methodology

The empirical analysis is based on interviews with managing directors and R&D executives in eight firms, conducted in two rounds. The first round covered three of the largest and most mature actors within electronics, and focused on issues spanning from overall competence upgrading to the organization of specific innovation projects. A survey questionnaire was then developed, and sent to the 42 member firms of the Electronic Coast and Engineering Coast networks. The survey obtained a total of 31 responses, equal to a response rate of 74 per cent. Information obtained on mechanisms for competence upgrading where used to group firms according to their "mode" of learning and innovation (Berg-Jensen, Johnson, Lorenz, & Lundvall, 2007). Five follow-up case studies where then conducted to ensure a sample which covered both clusters and each of the different modes identified. Interviews have also been conducted with key personnel at Vestfold University College, in addition to numerous informal conversations and the use of material documenting relevant internal strategy processes from late 1990s until present.

Conceptual framework

Industrial knowledge development and innovation

Economists from Adam Smith and onwards have conceptualized development as a process which generate an ever-expanding range of differentiated products and technologies (Knell, 2008). As the stock of knowledge available for recombination diversify (Grossman & Helpman, 1991), the opportunities for new technology development exponentially grow. 'What firms do ' is therefore identification, coordination and integration of diverse external knowledge inputs (Kogut & Zander, 1996). These are identified through ongoing processes of innovation search. Intentional and unintentional exposure to information defines the *search spaces* of corporate enterprises (Katila & Ahuja, 2002). Evolutionary theorists (Nelson & Winter, 1982) have argued that the more diverse the search space is, the better are the effects of the alternatives selected. Empirical studies have found the impact of innovation search on subsequent technological evolution to be contingent on spanning organizational boundaries and product domains (Rosenkopf & Nerkar, 2001) and to be improving with the diversity of information sources used (Laursen & Salter, 2006). These studies points out that the use of mature technologies from outside own sector boundaries can provide as strong an impetuous to innovation as new technologies developed by own sector (Katila, 2002) and that search should target knowledge domains characterized by lack of shared experiences (Hargadon & Sutton, 1997; Majchrzak, Cooper, & Neece, 2004) rather than similarity. Successful search may trigger the need for subsequent collaboration. Collaborating firms gain access to the tacit components of their partners' knowledge bases, and new knowledge is created which add to the stock of knowledge held by the firms involved. The different actor groups with which collaborative relationships may form differ in what knowledge and problem-solving capabilities the may contribute, at what stage of the innovation process. The successful identification of alternatives through search and transfer of knowledge through collaboration is dependent on the absorptive capacity of firms. This capacity is defined partly by the existence of prior related knowledge, which forms the basis for interpretation and transformation. It is also partly defined by the knowledge systems established and operated by firms, which form the basis for attention allocation, communication and subsequent learning (Bosch, Volberda, & Boer, 1999; Ocasio, 1997; Zahra & George, 2002).

The knowledge systems maintained by firms reflect their dominant “modes of innovation”(Berg-Jensen et al., 2007). The core of the “science-technology-innovation” (STI) mode is R&D departments of firms, linked externally to recruitment of highly skilled individual researchers, the use of epistemic communities as search space and collaboration with science system actors. The outcome is explicit knowledge, which – importantly - travels well but require adaption to contexts of application before it transforms into innovation. The strength of the mode lies in its ability to draw on and push disciplinary frontiers, explore fundamentally new knowledge independent of specific contexts of application and provide the basis for radical innovations. This is also its Achilles heel; as it is less able to mobilize and develop the knowledge necessary for its output to transform into large-scale industrial application. This means that it does not easily, in itself, translate into industrial activity (Karlsen, Isaksen, & Spilling, forthcoming). The core of the contrasting “doing-using-interacting” (DUI) mode is learning work organizations linked to external value chain actors in various forms. This model manages to mobilize and link experience-based knowledge originating in different parts of the organization and value chain; thus ensuring that a stock of knowledge which is context-specific and application-oriented continuously evolves. This sustains an ongoing stream of incremental innovations along established technological development paths and drives the development of highly specialized knowledge assets; but for the same reason comes with the danger of lock-in. Thus, at both firm and regional levels it can be argued that science-based and experience-based knowledge are complementary; in that the impact of either one on firm innovation or regional dynamics is reinforced by the co-existence of the other (Athey & Stern, 1998; Milgrom & Roberts, 1995).

The activities of individual firms in a regional setting may contribute spillovers into the regional system, which then, depending on the diffusion and absorption capacity of the system as a whole, are made available to other firms or used as basis for new firm formation. But as the process of specialization and diversification of inputs available occur on an international scale, geographically bounded search, collaboration and knowledge transfers create a potential for lock-in (Narula, 2002) to diminishing return paths. The high cost of establishing extra-regional linkages may combine with the low marginal cost of continuing to use existing ones (ibid); causing actors to over-search local environments (Katila & Ahuja, 2002) which do not contain the technological novelties or complementary capabilities needed to sustain innovation-based industrial dynamics (Bathelt, Malmberg, & Maskell, 2004; Graf, 2010). The successful establishment of regional firms as knowledge and information gravitation points in global networks (Coe, Dicken, & Hess, 2008; Herstad, Bloch, Ebersberger, & Velde, 2010) increases their individual exposure to information and knowledge diversity, hence increasing both innovativeness and economic performance at the firm level and creating a potential for richer regional spillovers. But it comes with less attention towards local collaborative linkages. Thus, recent research has focused on uncovering the conditions under which various forms of actors combine external-to-the system sourcing of novelty with internal processing and diffusion (Graf, 2010; Morrison, 2008).

Research has also focused on the regional knowledge diffusion mechanisms which remain in play even under conditions of strong internal value chain fragmentation, and thus explain observed clustering tendencies. As experience-based, tacit knowledge predominantly move through face-to-face interaction and with people(Lam, 2000), and the majority of job moves occur within regions (Ron Boschma, Eriksson, & Lindgren, 2008), recent analyses emphasize the role of labor market mobility (Eriksson & Lindgren, 2009) and personal network formation (Agrawal, Cockburn, & McHale, 2006; Dahl & Pedersen, 2004) independent of formal collaborative ties. Clusters of similar or related economic activities have been shown to the associated with particularly high degrees of such labor mobility (Eriksson, Lindgren, & Malmberg, 2008; Malmberg & Power, 2005); found firms to be able to absorb more diverse competencies if they are recruited locally (Ron Boschma, Eriksson, & Lindgren, 2009) and pointed to the importance of mobility between research-conducting firms and those which do not (Maliranta, Mohnen, & Rouvinen, 2009). Another important mechanism is spin-offs, i.e. the establishment of new firms to commercialize ideas originating in industry or research communities. These tend to cluster around their parent firms, and can provide strong growth impetuous into the regional system.

The impact such within-region knowledge diffusion is intimately interwoven with the composition of the industrial structure, i.e. the set of firms between which knowledge diffuse (Lazaric et al., 2008). *Agglomeration economies* (Beaudry & Schiffauerova, 2009) arise from a high degree of regional specialization, and consequently the formation of a "thick" and highly specialized labor market, a common supplier infrastructure and a common research infrastructure upon which technologically similar firms may draw. Cognitive proximity – similarity of activities - combined with co-localization is said to foster trust conducive to information sharing and collaboration, and enable local spillovers to diffuse and be absorbed with little friction. However, homogeneity substantially reduces the likelihood that these spillovers may enter into combinations which are truly novel, and increases the likelihood of negative technological lock-in. It also comes with the risk of competition between firms operating in similar markets; and of exogenous business cycle shocks upon the cluster as whole rather than individual firms. Others have therefore argued that diversity rather than specialization in the regional industrial structure is more conducive to knowledge diffusion and innovation. Diversity provides the basis for knowledge diffusion between technologically different activities, and hence for so-called *urbanization economies*. Diversity is assumed to *'…facilitate more radical innovation as knowledge and technologies from different sectors are recombined, leading to completely new products or technologies'* (Frenken et al., 2007:6-8). But diversity comes with the risk of fragmentation (Tödtling & Trippl, 2005) caused by cognitive distance (Nooteboom, 2000). Regional diffusion mechanisms are therefore needed to bridge cognitive distances and accelerate processes of reconfiguration in the intersection between diverse competencies already present (Philip Cooke, 2007; P. Cooke, 2008; Lazaric et al., 2008; Simmie, 2003).

Constructed knowledge diffusion infrastructures

This point to the importance of regional knowledge development, accumulation and diffusion infrastructures which operate independently of, or complementary to, local supply chain collaborative linkages and labor markets, and are able to explore new combinations on a broader basis. Examples of such include regional business and technology councils, regional development organizations and different labor training and mobility schemes. However, these are also mechanisms which are often a) dependent on the commitment of specific, leading firm actors and the successful definition of common interests and objectives among a set of diverse firms; thus vulnerable to fluctuations in such commitment (see e.g. B. T. Asheim & Herstad, 2005), and b) attempting to build, or even presupposing, commitment to local *collaboration* which is contradicting the need of individual firms to collaborate internationally. In addition, they may c) experience problems in adapting to circumstances which evolve with structural change, even when this structural change can be attributed to the effectiveness of the infrastructure (ibid).

Universities and university colleges may therefore play an important role in this infrastructure, in that they constitute a stable, third party actor which may operate independent of individual firm or sector preferences , yet adapt teaching and research to regional potentials and demands (Cummings, 1998; Goddard & Chatterton, 2003); and as they may intervene through the labor market and by supporting the local information ecology, rather than by forcing local collaboration between firms increasingly embedded in international linkages. They can help to integrate previously separated areas of technological activity and thereby unlock and redirect knowledge that is already located in the region but not being put to productive use (Lester & Sotarauta, 2007), and they can contribute to maintaining ad developing a specialized knowledge platform upon which different firms may draw. The core contribution by the university is therefore still education, and by contributing a public space for ongoing local conversation about the future of technologies and market. By means of education, they enrich the local labor market and contribute to the formation of personal ties across industrial firms; independent of collaboration. By conducting activities perceived as relevant by a broader set of firms, they may also attract the attention of research personnel and contribute to the reinforcement of personal ties and idea exchanges across such firms. Universities may accumulate knowledge from a broad specter of channels related to scale (regional, national and international) and industrial sectors, and thereby act as a knowledge bank enabling accumulation and diffusion independent of specific industrial actors. This illustrate that although the ability of the university college to accumulate and diffuse relevant knowledge into the regional innovation system may be contingent on its collaborative relationships with industrial actors; this role cannot be understood merely by considering the outcome of such collaboration for the individual firms engaging in it. Yet, this in turn presupposes that universities and university colleges position themselves to play a different role than that of technology production at arm's length from industry: They must interact with and learn from industry (Becher & Parry, 2005).

Consistent with this, an increasing amount of empirical studies (Balconi & Laboranti, 2006; Bekkers & Bodas Freitas, 2008; Daraio & Bonaccorsi, 2007; Kaufmann & Tödtling, 2001; Ponds, Oort, & Frenken, 2010; Varga, 2009) have shown that collaboration and interaction between university and industry is highly beneficial and cost effective way to develop new knowledge and technology (Etzkowitz, Webster, Gebhardt, & Terra, 2000), and more so than the 'linear' and often arms-length processes sought stimulated by different technology transfer and licensing schemes. Yet, these studies have also shown how the relationship between industry and universities is structured by the specific knowledge conditions involved (Bekkers & Bodas Freitas, 2008; Ponds et al., 2010), and consequently that the knowledge production and diffusion role of the university cannot be understood independently of such specific local circumstances.

University-industry dynamics in context

Industrial knowledge development and networking

First we need to consider the knowledge bases developed by industrial firms (B. T. Asheim & Coenen, 2005), and how these are reflect in distinctive modes of and geographical configurations of external innovation networks. In order to approach this systematically, we draw on survey information indicating which mechanisms for competence upgrading which are perceived by firms as most important. This information is used to construct a set of indicators which describe the importance of competence upgrading by means of "doing, using interacting" (DUI) and "science, technology, innovation" (STI) respectively. Indicator construction, reliability and descriptive statistics are given in table 1 below.

Table 1: Modes of innovation indicator system

Modes operationalized	
DUI mode composite indicator 1 (high importance) – 4 (not existent)	**Items entered:** **Stated importance (1 high – 4 not used) of:** Competence upgrading through daily work Competence upgrading through teamwork Competence upgrading through customer interaction Competence upgrading through supplier interaction
Reliability (Cronbachs alpha)	0,792
Range	1 (high importance) – 2,8 (lowest importance)
Mean	1,6214
STI mode composite indicator 1 (high importance) – 4 (not existent)	**Items entered:** **Stated importance (1 high – 4 not used) of:** Competence upgrading through R&D Competence upgrading through HEI/university interaction Competence upgrading through research institute interaction
Reliability (Cronbachs alpha)	0,680
Range	1 (high importance) – 3 (lowest importance)
Mean	2,0119

These indicators formed the basis for the grouping of firms according to their dominant knowledge development logic, using hierarchical cluster analysis. In accordance with Berg-Jensen et al (Jensen, Johnson, Lorenz, & Lundvall, 2007), we find the two distinct STI and DUI groups, in addition to a large intermediate group of companies which combine the two modes. Basic descriptive statistics on these clusters are given in table 2 below. Based on this categorization, a total number of 7 firm interviews were conducted, mainly with chief executive or technology officers.

Table 2: Survey firms by innovation mode.

	Combined mode	STI mode	DUI mode	Total
Number				
Electronics	14	2	5	21
Engineering	3	2	2	7
Mean indicator scores				
DUI mode	1,5294	2,4500	1,3714	2,0119
STI mode	1,6863	1,8333	2,9048	1,6214
N	17	4	7	28

A group of seven companies state that competence upgrading occur primarily through daily, team-oriented work processes and interaction with customers and suppliers. R&D investments are limited, and those conducted predominantly target specific customer needs and the refinement of existing technologies (see table 3 below). Four of these are electronics manufacturers; producing either specialized components or delivering manufacturing, test system and logistics services to system integrators. Two are large maritime engineering and service providers; and all are affiliated with multinational corporate groups. Innovation search patterns are highly oriented towards the mobilization of ideas and information already existing within own organization and parent group network; and external search and collaboration patterns reveal the overwhelming importance of client firms - located elsewhere in Norway or abroad. In addition, they maintain international search spaces with a distinct focus on their sector communities in general and supplier networks in particular. Continuous, complex and context-specific problem-solving best describe innovation activities.

Inputs from more systematic knowledge development processes enter, but it does so indirectly, through customer and supplier firms located elsewhere. For instance, engineering firms in the region are heavily dependent on interaction with leading subsea system designers, who in turn collaborate with specialized Norwegian research communities. They are also dependent on collaboration with certification agencies such as DNV, which provide quality and compliance control on behalf of authorizes and customers. Competence upgrading by means of external recruitment is considered of relatively low importance, for three main reasons: First, because such competences are not necessarily readily available in external labor markets. Engineering firms experience overall supply deficits, combined with an increasing shortage of engineers with hands-on experience from large vessel or offshore construction. Electronics firms in this group, on the other hand, show a very low rate of employee turnover, which in itself limit renewal through recruitment. Third, because most remaining activities within electronics have strong firm specific components to them; which translate into requirements of firm-specific training and reinforces the reluctance of the companies with respect to hiring new staff.

Table 3: R&D investments by mode of innovation.

	R&D intensity	**Orientation of R&D** (average shares of R&D conducted by target area)			
	Average share of sales	Customer needs	Refinement of existing technologies	New product development	Long-term research
Combined mode	24,71	28,75	37,81	24,38	9,06
STI mode	46,75	5	28,75	45,00	21,25
DUI mode	6,29	53,60	35,01	24,40	0
Total	23,25	29,92	35,77	27,68	9,20

The mirror image of this is found in another small group of companies which state that core competencies are developed primarily by means of systematic internal R&D, linked to external science system actors; and that learning through daily, team-oriented work processes contribute very little if anything to building these competencies. The four firms constituting this group is found within advanced subsea engineering (recent spin-offs from another engineering incumbent), in the interface between electronics and life sciences, and in the development and production of optics and display technologies. Although both customers and suppliers are present as information sources and collaboration partners; no single company state that customers are of high importance and external search and collaboration is distinctively oriented towards the science system. Reflecting this orientation is a very high R&D intensity, and a large proportion of this R&D target long-term basic research and the development of new technologies. The external orientation towards science is reflected in an internal competence base which is stated as easily maintained by external recruitment and in which personnel with education at PhD and master levels are dominant.

DUI and STI mode companies are opposite extremes surrounding a population of companies in which competence evolve by means of daily, team-oriented work linked to external customer and supplier interaction; combined with systematic R&D linked to science system interfacing. These firms thus integrate science-based and experience-based knowledge internal to their organizations, and constitute the core of the regional knowledge base. They are either system integrators who deliver complete product systems to demanding final end uses at e.g. hospitals, airports or vessels; or component manufacturers which operate in markets such as aerospace, medical and subsea. They share the DUI focus on customer search and collaboration externally, and actively search their internal stocks of accumulated daily work and R&D –based experiences. The existence of an R&D-based knowledge stock is indicated by a much higher R&D intensity than what is found among DUI firms; and by a much more even distribution of this R&D in the range from long-term basic research to specific customer needs. Yet, they are distinctively less oriented towards science system than customer search, and both long-term research and more short-term product development is to a very large degree shaped by existing or expected customer needs.

The importance of extra-regional linkages is most clearly visible at the level of targeted innovation activities, i.e. innovation collaboration and search. For instance, whereas nine intermediate mode firms state that localized information flows are important for overall competence upgrading, only two such firms state that the same transmit information which is used directly as inputs to innovation. At the same time, most firms in this group state that international information flows specific to their sectors as moderately or very important. Only the DUI group remains heavily oriented towards localized information flows; while combining this with orientation towards global sector-specific communities similar to that of the intermediate group.

Yet, the region remains an important venue for those processes which resist formalization, planning and codification, i.e. competence upgrading and search. Just above half of the survey sample state that information flows within the regional "milieu" is somewhat or very important for own competence upgrading purposes. Interviews confirm that this reflects the reliance of these firms on the local – informal - information ecology, and its overlapping ties of personal networks and arenas for face-to-face contact. The picture comes even more distinct when we consider innovation search; as almost all companies outside the STI group that regional information flows are somewhat or highly important either for competence upgrading or for search. Contribution to this information ecology is formal networks such as Electronic Coast and Avanse, and the activities at VUC and the affiliated Norwegian Centre of Expertise in micro- and nanotechnology. Contrasting this is firms in the STI group, in which no single state that regional information flows support their search activity and only one single firm perceive it as important for own competence development purposes.

The university college is clearly present as information source and collaboration partners to the intermediate mode group. Half of this group state that the regional science system is used somewhat or extensively as source of information input to innovation; and all of these collaborate actively with it. This is combined with a strong orientation towards external science system search: More than half state that external science system search provides important inputs to innovation; all but two of which collaborate actively with the regional science system. This places these firms as gatekeepers between external and internal scientific communities (Graf, 2010). However, it is largely the mature firms with strong internal capabilities and broad external networks within and outside the region who maintain collaborative relationships with the regional science system. Our interviews reveal that STI group companies stating collaboration with the regional science system either orient themselves towards specialist consultancy or certification agencies, or, in one case, in essence have *outsourced* most of their technological development to the UC.

The changing regional knowledge diffusion infrastructure

The overall picture is therefore one in which a) scientific knowledge only constitute one of many components entering into firm innovation, and b) these various components increasingly are outsourced outside the region. The latter had developed and institutionalized several diffusion mechanisms outside the realm of the regional university, which are undermined by such development trends. The Avanse network operates as a collaborative arrangement between electronic- and microelectronic firms, and enables exchanges of high-skill production personnel. However, its role is diminishing with overall downsizing of production and thus with decreasing reliance on those specialized production skills which it primarily serve to contain within the region and diffuse between firms. No similar mechanism exists within the engineering cluster. In 1998, Vestfold University College (VUC) led the formalization of the Electronic Coast[1] project, supported by

[1] http://www.electronic-coast.no/

the public Regional Innovation Program. This had started as an informal network of local business managers working at electronic- and microelectronic companies. The subsequently defined that the role of the EC-network was to stimulate entrepreneurship within the industrial cluster of electronic and microelectronic companies (Finsrud, 2007). The re-vitalization process of the EC-network was anchored and organized as a broad participative process involving participants from the University College, Vestfold County Council (VFK), Horten Municipality and electronic and microelectronic companies. Yet, new firm formation within electronics remains largely non-existent, and the attention of existing firms is increasingly directed elsewhere, towards more individually relevant but geographically distant sources of innovation process inputs.

By the late 1990s several companies expressed dissatisfaction with the lack of more substantial commitment from VUC. In particular, teaching and research was criticized for been outdated and the educational profile for not being adapted to the specialized needs of the regional industry. At the same time, the electronics industry was at this point beginning to feel the combined effects of increased international competition at the component supply and production sides. Leading system developers pointed out that their need for long-term, high-risk investments in complex internal R&D to fight off this competitive pressure was financially difficult to combine with the need for firm-specific investments in the competences of new researchers. Something had to be taken out of this equation, and the latter was the most obvious choice.

VUC responded from the beginning of 2000, following the election of new principal and new faculty deans. Based on the experience from the EC-network, the Faculty of Social Sciences developed a tailor made management educational program, aiming at improving both management practices and co-operation within the industrial environment. The program was designed for the specific purpose of allowing participants to share their work experience (Gausdal, 2007), and thus drew its content from these experiences. In 2003 VUC decided to establish a new master program in microsystem technology, which entailed large financial and professional challenges. As a medium sized university college, VUC had almost no experience of managing such advanced and expensive master program. In order to get a master program officially certified and considered relevant by industry, VUC needed to obtain the necessary specialized competences; and invest in expensive supportive infrastructure such as clean room laboratory and production equipment. VUC therefore made an agreement with large, leading electronics companies. These where willing to share their technical expertise as tenant professors, and to donate necessary research equipment to the university college (Nilsson, 2006). VUC also recruited several key personnel from local companies (professors, phd.d and technical assistants). These initiatives and processes combined enabled VUC to establish the foundation necessary for more self-sufficient activity within the MEMS field.

At the university college side, this involved internal tensions because it entailed the channeling of attention and financial resources towards one specific area, at the expense of other well established areas. In practice, this meant a substantial reorganization of the engineering department, and downsizing of former academic strongholds. At the industry side, the content of the program was considered critical because it would directly contribute to defining the future "platform" technology for the cluster as a whole. MEMS technology was chosen partly as a result of pressure from leading firms; and legitimized with reference to this being a general purpose technology applicable – and increasingly relevant – across most segments of advanced electronics. It is also a technological field with potential for drawing heavily on other high velocity fields, such as biotech. Others still claim that a stronger emphasis on the “packaging” of advanced electronic components would have better reflected the breadth of activity in the region; contributed more to maintain production capacity and thus competences in the region and added more immediate value the cluster as a whole. Some firms also saw the build-up of competences at the UC by means of recruitment from industry as a direct threat to their own internal competence base.

Yet, with new staff-members the Faculty of Science and Engineering became more attractive as a partner in several large-scale joint research programs, such as NEWPACK[2] and MULTIMEMS[3], run by staff member from the University College in partnership with local industry and the national research institute SINTEF. Partly based on external founding related to such collaboration with industry, and partly because of the knowledge transfer into the UC which came with them, the Faculty of Science and Engineering manage to finance and build a new institute with a bachelor and master degree program in MEMS technology by 2005. This institute today has 30 employees, hosts 25 phds and is in the process of applying for certification of its own PhD program. The subsequent establishment of a National Centre of Expertise in Nano- and Microsystems engineering marked a shift towards a more active role for the UC as platform technology *developer* – based on the competence based it had built through its intimate relationship with regional industry. In 2008, the NCE partnership revived Microtech Innovation, established in 2003 by local government and three leading industrial firms to serve as a commercialization vehicle. This defined MTI not only as the main commercialization engine for NCE and VUC technology, but also as a national innovation and commercialization player in the micro- and nanotechnology area. The MTI board and shareholders approved a new business plan in 2010. As of this year, MTI has project management responsibility for the Norwegian Centre of Expertise, and now also incorporates the networking organization Electronic Coast.

However, this potential does not at present materialize as growth or structural change. The role of VUC as contract research partner for the electronics industry is limited; partly because firms operating outside the MEMS area perceive its activities as irrelevant, and partly because firms within this area consider contract research technologically difficult and collaboration strategically problematic. It involves large resources spent on communicating tacit, contextual knowledge to the contract partner, and thus entails exposing proprietary technological knowledge to VUC researchers and – most problematically - students. Its role as a collaboration partner is further limited by the deepening embeddedness of firms in their respective global innovation networks, and what should be its main role by working through the local electronics industry labor market is constrained heavily by the lack of growth among existing firms. Against this background it is not surprising to find a strong emphasis in regional development plans on nurturing new firm formation within electronics, based on the competence base now built within VUC. Yet, after Sensonor established MEMSCAP in 2000, there have been few signs of new firm formation *within* electronics based on competences *on* electronics. Part of this is again directly attributed to the complexity of technologies involved and the prohibitive need to build complementary capabilities and networks.

[2] NEW knowledge and technology for PACKaging of Microsystems (NEWPACK) was a collaborative research program founded by the Norwegian Research Council in 2003 - 2006.

[3] MultiMEMS N: Manufacturing Cluster Providing Multi-functional MEMS Services to the Industry is a collaborative research program founded by the Norwegian Research Council from 2003 – 2004.

Collective mobilization and commitment

This reconstructing of the regional knowledge development and diffusion infrastructure towards one centered on Vestfold University College rather than various industry-driven networking initiatives, presupposed large-scale initial knowledge transfers *from* industry and *into* VUC. This suggests that regional science system actors should be cautious about defining their main role as one of *delivering* the results of academic research to a set of existing industrial firms. While a limited number of large universities which are internationally leading within their technological fields may boost regional development by means of such linear commercialization and spillover processes; the Vestfold case show clearly how industrial firms link up with science system actors elsewhere for the purpose of sourcing advanced, modular science system outputs while remaining dependent on those specialized knowledge assets which enable their commercialization. Hence, it is the accumulation, further refinement and diffusion of these specialized assets which should be the main concern of those universities and university colleges which cannot compete at disciplinary scientific frontiers.

The development of specialized education programs is critical, because it enables the build-up of new internal university competences and other “third mission” activities to be linked directly to the primary defined roles of universities and university colleges. This raises the legitimacy of the effort internally in the organization, lubricates the embedding of the new competences within it and contributes to decoupling these competences from the industrial organizations in which they originally developed. Furthermore, it links directly up to the *main mechanisms for regional knowledge accumulation and diffusion* under conditions of value chain fragmentation and globalization; namely the regional labor market, mobility within it and the resulting formation of personal ties across independent companies. Once an education program “core” has been established, the VUC case illustrate how this may simultaneously provide the basis for more advanced research activities and increase the overall attention received by the university college from actors spanning the range from local industry to research communities abroad. With this may follow the development and institutionalization of labor markets which in essence overlap between the spheres of industry and university (Lam 2007). Combined, this vastly increases the ability of the organization to attract students and researchers from abroad, thus further strengthening its ability to support regional labor market dynamics and to serve as a locus for information sharing, idea exchanges and personal network formation.

The mobilization and commitment of industrial actors required perceptions of future relevance; and necessary choices concerning strategic orientation and content necessitated that divergent views on this from industry could be overcome. The process of transformation at the university college side similarly involved establishing legitimacy within a broad range of professional communities; and institutionalizing the third-mission role of contribution to regional development in a context where individual researcher disciplinary excellence and inter-department competition for scarce resources remain key components of the academic model of work organization and motivation (Becker & Parry, 2005, Gibbons 1994). Furthermore; it involved – and still involve – accepting that the visible returns from these activities in the form of firm growth and profit will come outside the realm of the VUC organization in itself; as social returns at the level of the regional economy rather than private returns from licenses and patents at VUC. This is part and parcel of successfully exercising a knowledge diffusion role which rest on interactive learning in the relationship with industry, and again points to how this role differs from one of research commercialization.

Conclusion

This paper has analyzed how a regional innovation system has deconstructed as sets of value chain collaborative linkages, and asked how regional knowledge diffusion infrastructures can be built around firms when these are embedding in global innovation networks. It point to the enduring, even increasing, importance of the local information diffusion ecology; and the potential for innovation to emerge at the intersection between regional knowledge assets which are already there. In order for the information ecology to survive, and the exploration of cross-sector linkages to occur, a stable, committed and inclusive knowledge accumulation and diffusion infrastructure is needed.

This suggests that the real potential for the university college may lie not so much in directly supporting the current – specialized - activities of existing firms, as in a combined effort of maintaining – through education programs drawing partly on competences developed by industry – a specialized regional knowledge base, and in providing an external to industry platform for the exploration of how these competences can feed into and be fed by activities outside their current domain of application. Other regional networking initiatives and institutions, such as those represented here by the Electronic and Engineering Coast networks, may provide important arenas for dialogue between existing firms and within established sector boundaries, but do not have the capacity to serve externalization and exploration roles outside and across such boundaries. In the case of Vestfold, specialized competences initially contained within a limited number of advanced industrial firms have now in essence been "externalized", subjected to further scientific scrutiny and development, and made available as a platform technology for firms within and outside the realm of microelectronics. Similarly, competencies in areas such as logistics and project management built through VUC interaction with engineering firms are also de facto available to firms outside the realm of engineering. Examples are still anecdotal, but include the exploration of MEMS technology by firms in an adjacent cluster developing water purifying technologies, and the exploration of advanced logistics competences by local producers of up-market food. These cross-sector linkages are directly attributable to the existence of such competences within VUC, and its efforts at further developing these through research activities.

Yet, this knowledge development and diffusion role presupposes a) that the focus on traditional linear technology commercialization efforts is reduced, in favor of a more proactive approach at the side of the regional university college towards exploring how novel combinations may be created based on the specialized competences it now possesses. Then it presupposes b) that a certain industrial base is already present in the region. University colleges may contribute the knowledge diffusion capacity needed to *explore* and *identify* new forms of technological relatedness; but may not produce its constituent parts.

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